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THE INDIAN AND NATURE

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From an extended study of the Siouan tribes of the Plains Indians, it is evident that their tribal organization and rites are based on concepts derived from observations of Nature.

These Indians belong to an observant, thoughtful, out-of-door people who for generations have lived on intimate relations with an unmodified environment. No animal but the dog was domesticated, all creatures pursued their own mode of life. With few exceptions plants were uncultivated, undisturbed in their manner of growth. No highways broke through the prairies or woodlands, the winding trails of animals served as footpaths for man. There was nothing visible to suggest any break in the continuity of the natural relation between man and his surroundings. It was amid such untouched, unforced conditions that these people attentively watched the various phases of life about them and pondered deeply on what they saw.

The Indian discerned that everywhere dual forces were employed to reproduce and so perpetuate living forms. The fructifying power of the sun was needed to make the earth fruitful and only on the union of the two, the sky and the earth, was life in its various forms made possible. Upon these two opposites, he projected human relations and made them, to a degree, anthropomorphic, the sky became masculine, the earth, feminine. Finally, he was led to conceive of the cosmos as a unit, permeated with the same life force of which he was conscious within himself; a force that gave to his environment its stable character; to every living thing on land or water the power of growth and of movement; to man it gave not only his physical capacities but the ability

to think, to will, to bring to pass. This unseen, undying, unifying force is called by the Omaha and cognate tribes, Wakonda. Through Wakonda all things came into being, are ever related, and, more or less interdependent. Consequently, Nature stood to the Indian as the manifestation of an order instituted by Wakonda wherein man was an integral part. To this order he turned for guidance when establishing those means, religious and secular, that would insure to him, individually and socially, safety and continuous life.

Finding himself to be one of a wide reaching family, the Indian planned his tribal organization upon the type of that family. He divided the people into two great sections, one to represent the sky, the other, the earth. Each of these sections was composed of a number of kinship groups, called by the Indian, To^{n}-wo^{n}-gtho^{n}, meaning, village. (These villages are spoken of as clans or gentes by students of our race.) Each village stood for some one of the forms of life seen in Wakonda's instituted order. The sky was the abode of the sun, the moon, the stars, the storm cloud with its thunder and lightning. The earth, with its land and water was the abode of the trees, the grasses, and the various animals so closely allied to man and his needs. The tribal organization aimed to mirror man's environment. The tribal rites were instituted to provide a means by which the people could approach the invisible power, believed to abide in Nature, for help, to secure food, safety and long life.

Each village (gens) had its own ceremony which was also a component part of the tribal rites, wherein all the villages (gentes) were thus represented. The ceremony of each village (gens) had a central subject, some form or force, having its abode in the sky or on the earth, and represented by a symbol. The name given to this symbol by the Omaha and cognate tribes, is I-ni-ka-shi-ki-the, a term composed of, I, by which; ni-ka-shi, a part of ni-ka-shi-ga, people; ki-the, make themselves; and means, that by which they make or designate themselves a people. (Students of our race have applied to this symbol the term 'totem.') As has been shown, this symbol referred to one of the forms or forces belonging to Nature as instituted by Wakonda, therefore represented in the tribal organization and the tribal rites. The symbol had a sacred significance to the people of the village (gens) in whose ceremony it held the central place. It bound the people of the village (gens) together by a sacred tie, made them distinctive among the other villages (gentes) that composed the tribe, and, it was a link between the people of the village (gens) and the invisible Wakonda. The symbol belonging to a village (gens) is always referred to metaphorically in the name

by which the village (gens) is known, and, the symbol is also treated in the same manner in the personal names ceremonially given to every child born within the village (gens). The symbol may be an animal, as, the buffalo, or a force, as the wind, and the people be spoken of by the names of the symbol of their village, as, the buffalo people, or the wind people. There are certain articles that are regarded as associated with the different symbols. The people of a village (gens) treat with marked respect and never taste or touch such articles as are supposed to be associated with their sacred symbol.

Those villages (gentes), whose symbols are of some form or force that has its abode in the sky, have their unchangeable place in the sky section of the tribe, and those, having symbols that pertain to either the land or water, have their fixed place in the earth section. During the time when tribal rites are performed, the tribe is oriented, that the people may face the ever recurring day, a symbol of life. These rites may be grouped into three classes: Those which are an appeal for the securing of food; to this class belong those rites that relate to the maize and to hunting. Those that pertain to unity and peace; to this class belong the ceremonial giving of a tribal name, the Wa-wan ceremony and certain social customs. Those which relate to war, the defence of the tribe, both as to its food supply and the life of the people. The prayer for long life, that occurs under various forms throughout the rites is understood as an epitome of these essentials to individual and to tribal life.

The Omaha distinguishes tribal rites from other ceremonies by applying to the former the term Wé-wa-çpe. The word is compound; we, signifies an instrument, a means by which something is done or brought to pass; wa-çpe, means, orderly conduct, thoughtful composure. The word, according to its context can mean, religion, law, or any similar institution. As here used it signifies a means to bring the people into order, into thoughtful composure. This term applied to tribal rites, bears testimony to a discriminating observation of the social value of religious observances, not only as a power to hold the people together by the bond of a common belief, but, as a means to augment the importance of self control and, of submission to authority. Rites designated as wé-wa-çpe, were believed to open a way between the people and the mysterious, unseen Wakonda, and, any careless or irreverent act toward them, subjected the offender to supernatural punishment.

These rites are composed of dramatic acts, the recitations of rituals and the singing of ritualistic songs. In these are embodied the myths, and allegories in which the genesis of man and his relation to Nature

are set forth. In the stories, symbols and metaphors are freely used, often in a highly imaginative manner and not infrequently touched with poetic feeling. By these means, the Indian's mind sought to bridge the gulf he recognized as stretching between him and the forms and forces of Nature that had so direct and yet so subtle a relation to his existence. These myths, allegories and metaphors form a nimbus about these rites that both illumines and yet makes elusive their meaning.

The Omaha, on his entrance into life is met by one of the tribal rites. He is introduced to the cosmos by the priest, standing outside the tent there, raising his right hand to the heavens, palm outward, he intones in a loud voice the following ritual hymn:

Ho! Ye Sun, Moon, Stars, all ye that move in the heavens;
I bid ye hear me!
Into your midst has come a new life!
Consent ye, I implore!
Make its path smooth, that it may reach the brow of the first hill.

The Winds, Clouds, Rain, Mist, that move in the air;
The Hills, Valleys, Rivers, Lakes, Trees, Grasses of the earth;

The Birds of the air, the Animals of the forest, the Insects that creep among the grasses and burrow in the ground are addressed in the same manner. Finally he cries:

Ho! All ye of the heavens, all ye of the earth,
I bid ye hear me!
Into your midst has come a new life!
Consent ye, consent ye all, I implore!
Make its path smooth, then shall it travel beyond the four hills.

Infancy, Youth, Maturity, Old Age, are the four hills across which lies the rugged pathway of life.

In the social life of the Indians many little dramatic acts occur significant of beliefs, that are difficult for a stranger to understand correctly. For example: A relative comes to the home of an infant and presents it with a tiny pair of moccasins with a hole cut in each sole. The Indian mother understands the tender wish conveyed by the act. The baby is thus recognized as an Omaha child, for the moccasins anticipate the ceremony in which the 'new life' is proclaimed a member of the tribe. The holes are a sign of usage, they express the giver's prayer for long life to the child. A person might enter the tent, see the tiny moccasins with the holes and exclaim: "What a long way the little one has traveled!" This too would be a prayer for long life to the child. If

an unseen messenger from the spirit world should approach the infant to bid it come with him, the child would be able to say, "No, I can't go with you, look, my moccasins are worn out!" and so, the baby would not be taken away from its mother.

Both garments and the manner of wearing them ceremonially are by the Indians invested with symbolic meanings. For instance: The Robe is significant of a man's duties or purposes according to the manner in which it is worn or adjusted about his person. The position of the eagle feather on a man's scalp-lock indicates the class of act which brought to the man the right to this war honor. Other regalia made up of different articles, each one of which has its special significance, present to the Indian warrior a picture, as of the battle field where he fought, defending his tribe, and won his honors. None of the articles employed to represent war honors or a special part taken by a man in any of the tribal rites are allowed to be used as mere adornments. A war honor can not be worn by a man until he has won the right to wear it, by the performance of a valorous act, that has been publicly recounted, approved by witnesses, in the presence of the tribe, at which time the honor appropriate to his act is accorded him, and he is authorized to wear the insignia belonging to the grade of his act.

Moccasins have a significance. Formerly each tribe had its own style of moccasin, so that a person's tribe would be indicated by the kind of moccasin he wore.

In the ceremony that marks the birth of the 'new life' into the tribal organization, the dual forces are present, the masculine sky and the feminine earth; the former, represented by the 'Four Winds' invoked to 'come hither' in the opening ritual song; and, the latter, by the stone placed in the center of the ceremonial tent. The time when this tribal rite took place was in the spring, "when the grass was up and the meadow lark singing." The child was about four years old and must be able to go about alone and unassisted. A tent was set up and made sacred, therein the priest awaited the children brought thither by their mothers, each child carried a new pair of moccasins. As the mother approached the tent with her child, she addressed the priest, saying: "Venerable man, I desire my child to wear moccasins!" and, the little one, carrying its moccasins, entered the tent alone. According to the Omaha rite and that of some of the cognates, the priest, after summoning the 'Four Winds' lifted the child upon the stone, where it stood in its bare feet facing the east, then the priest lifted it and placed it on the stone facing the south, again he lifted it and on the stone it stood facing the west, lifting it again, its feet rested on the stone as it faced the north, lastly,

the priest lifted the child and it stood on the stone with its face to the east. The priest sang the following ritual song. A free translation is given.

> Turned by the Winds, goes the one I send yonder,
> Yonder he goes who is whirled by the Winds,
> Goes where the four hills of life and the Four Winds are standing,
> There into the midst of the Winds, do I send him,
> Into the midst of the Winds, standing there.

The priest then puts upon the child's feet the new moccasins, makes it take four steps, and says: "Go forth on the path of life!" A personal tribal name was now given the child, one that belonged to its father's village (gens) and referred to the second symbol of its rite. This name was then proclaimed by the priest to the "Hills, Trees, Grasses, and all living creatures great and small!" in the hearing of the assembled members of the tribe.

In connection with the part symbolically taken by the Winds in this ceremony, it is interesting to note, that it was the duty of the 'Wind people' to put moccasins on the feet of the dead, that they might enter the spirit land and there be recognized and able to rejoin their kindred.

After a boy had ceremonially received his tribal name, on his return home, his father cut the child's hair in an established manner which was meant to typify the sacred symbol of his village. This manner of cutting a boy's hair was kept up until the child was about seven years old. The queerly cropped heads of the boys fixed in the minds of the children the symbols belonging to the different villages (gentes).

The symbolism attached to garments and the manner of wearing them, already mentioned, runs through the myths, allegories and metaphors, and figures extensively in the tribal rites.

A detailed presentation of the subject of this paper is impossible within the accorded limits, but from what has been given, glimpses have been obtained of the line the Indian has pursued in his endeavor to express his view of Nature and of the relation he believed to exist between its various forms and forces and himself.

In the tribal rites can be traced the gropings of the Indians' mind to find that power, greater than man, which was the source of visible Nature; to discover a way for man to approach that power so that he could receive help from it; also to search for the meaning of the activities that were everywhere apparent. The religious and social ideas developed through this search, extending, through generations, as the rituals give evidence both directly and indirectly, were gradually evolved and

formulated in the tribal rites, wherein was set forth, with unmistakable clearness, to the people, the importance of the perpetuation of human life upon the earth, and, of the recognition, that the life-giving power of Wakonda is ever present in all things that surround man.

THE MECHANISM OF ANTAGONISTIC SALT ACTION

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1. The work on antagonistic salt action has shown that we must discriminate between two distinct groups of such phenomena. The first group is represented by the counteraction of the toxic effects of a salt with a univalent cation by a salt with a bivalent cation. I showed in 1901 that all salts with a univalent cation rapidly kill the newly fertilized eggs of the marine fish *Fundulus* when the concentration of these salts exceeds a certain limit, while the addition of a very small (though definite) quantity of a large number of salts with a bivalent cation prevents or retards this injurious action.[1] Salts with bivalent anions had no such effect. The rôle of the valency of the cation in these phenomena of antagonism was unmistakable and was pointed out in the same papers as was also the relation to certain rules in the precipitation of colloids, but it was not possible to indicate an antagonistic action on colloids between salts with univalent and bivalent cations. I suggested later that the rapid death of the eggs in the salts with univalent cations was due to a diffusion of the salts into the eggs, while the addition of the salt with a bivalent cation prevents or retards this rapid diffusion,[2] and this suggestion was supported by later experiments.

It therefore appeared from these observations that the salts with monovalent cations increase the permeability of the membrane when their concentration exceeds a certain limit, and that the addition of a trace of a salt with a bivalent cation, e.g., $CaCl_2$, diminishes the permeability. This idea received support in the floating experiment of the writer with *Fundulus* eggs[3] and in Osterhout's experiments on the galvanic resistance of *Laminaria* in NaCl and $CaCl_2$ solutions.[4]

The second group of antagonistic phenomena is represented by the following experiments. In 1911 Loeb and Wasteneys found that a KCl solution in the concentration in which this salt is contained in the sea water is toxic for the marine fish *Fundulus*, while the addition of NaCl in a definite ratio (17 molecules or more of NaCl to 1 molecule of KCl) annihilates the toxic effect of KCl. Na_2SO_4 was about twice as

efficient for this purpose as NaCl.[5] I showed later that the poisonous effects of NaBr, $NaNO_3$, and other salts, could also be annihilated by the addition of NaCl[6] and the same was found to be true for the effect of acids.[7] Since a pure solution of NaCl does not diminish but increases the permeability of the membrane it was not possible to explain these cases on the assumption of an opposite influence of the antagonistic electrolytes upon the permeability of the cell wall. I have recently made some experiments in collaboration with Mr. McKeen Cattell which have led me to a theory which seems also to furnish the physicochemical analogue to this second group of phenomena of antagonism.

We found that the same concentration of KCl in distilled water causes the standstill of the heart of the embryo much more quickly than when contained in sea water. This experiment (which we will call experiment I) is simply a confirmation of the previous experiments of Loeb and Wasteneys on the adult fish, and it might be interpreted on the assumption that the permeability of the membrane for KCl is greater in distilled water than in sea water. But this explanation of experiment I is rendered impossible by experiment II which follows. Eggs were exposed to a KCl solution until the heart stopped beating. They were then equally distributed in distilled water and in sea water and it was observed in which of the two solutions the hearts began to beat first. The result was very striking. While the hearts of the eggs in the sea water began to beat again in a few hours, or in less than a day, those in distilled water often did not recover in a number of days. When their recovery failed to occur within reasonable time in distilled water the heart beat could be called forth in less than a day by transferring the eggs to sea water.

The recovery of the hearts poisoned with KCl depends upon the diffusing out of the KCl from the egg. If it is legitimate to assume in experiment I that in distilled water the KCl causes the heart to stop more quickly because the membrane is more permeable for KCl in distilled water than in sea water, we should expect that in the recovery experiment the hearts would also begin to beat sooner in distilled water than in sea water; since in the latter the membrane is assumed to be less permeable than in distilled water. Hence in sea water it should require more time for the excess of KCl to diffuse out of the egg than in distilled water, which is the reverse of what we observed. It is, therefore, impossible to explain these observations on the assumption that in distilled water the permeability of the cell membrane for KCl is greater than in sea water.

3. We next tried whether other substances acted like sea water, and

found that a great number of salts could replace sea water in the two above mentioned experiments. Thus m/2 NaCl or m/2 LiCl or $NaNO_3$ or many other salts retarded the poisoning effect of KCl upon the heart of the embryo and accelerated the recovery about as much as did sea water. We are, therefore, dealing here with a general salt action which increases in certain limits with the concentration of the salt and which varies for different salts. Thus it was found that for equal concentrations the citrates are much more efficient than the sulphates or tartrates and these are more efficient than the chlorides or nitrates; which indicates a valency effect of the anion.

A trace of acid when added to distilled water may also accelerate the recovery of the hearts poisoned with KCl. Bases have no such effect. Sugar solutions act like distilled water.

4. The question arises: How is it possible for salts (or acids) to retard the entrance of KCl into the egg or to facilitate the diffusion of KCl out of an egg which has been poisoned with this salt? All previous theories of antagonistic salt action (with the exception of the one proposed by Loeb and Wasteneys for the case of KCl and NaCl) have only considered three quantities: the concentration C_I of the poisonous salt (in our case KCl) in the outside solution, the concentration C_{II} of the injurious salt inside the membrane, and the "permeability" of the membrane. I am of the opinion that it is necessary to introduce another quantity, namely the concentration C_{III} of the poisonous salt at the boundary between the membrane and the outside solution. I assume, therefore, that there are forces at work (chemical or kindred) between the membrane and the poisonous salt in the surrounding solution (e.g., KCl) whereby this salt adheres or is attached to the external surface of the membrane in a concentration C_{III} which is different from C_I; and that C_{III} and not C_I determines the rate at which the salt diffuses into the egg. It is further assumed that the presence of other salts influences the (chemical or kindred) forces acting on the surface of the membrane whereby the concentration C_{III} at the surface of the egg is different from what it would be if the injurious salt (e.g., KCl) were alone in solution. *Whenever the influence of another salt is such as to diminish C_{III} we are dealing with a case of antagonistic salt action.*

5. In order to test this idea the writer made experiments in which he substituted a dye, namely neutral red, for KCl. He found that in the same concentration of neutral red the eggs of *Fundulus* are stained red more rapidly if the dye is contained in distilled water than in a salt solution or in a solution containing acid. He found, moreover, that the more dilute the solution of a given salt the less its antagonistic effect to

neutral red; and that sulphates inhibit the staining of the egg more powerfully than equal concentrations of chlorides. The same agencies which prevent or retard the entrance of KCl into the egg of *Fundulus* prevent or retard the staining of the membrane with neutral red.

If we stain eggs of *Fundulus* in neutral red and put them afterwards into distilled water or salt solutions free from stain, the eggs will be decolorized rapidly in salt solutions or in acid solutions, while they will be decolorized very slowly in distilled water. The decoloration occurs the more rapidly the higher the concentration of the salt, and more rapidly in sulphates than in chlorides.

The antagonism between the staining effect of neutral red upon the eggs of *Fundulus* and salts or acids is, therefore, parallel to that between the injurious effect of KCl upon the same eggs and salts or acids. In the case of neutral red we can see directly that the salt or acid diminishes the concentration C_{III} of the neutral red on the surface of the egg. When an egg stained in neutral red is put into a m/2 solution of NaCl or of NaCl + $CaCl_2$ or a m/8 solution of Na_2SO_4 streaks of the dye are seen to stream from the surface of the egg into the surrounding solution, while nothing of this kind occurs if the eggs are put into H_2O. Here we can ascertain by direct observation that the antagonistic action of the salt on the dye consists in diminishing the concentration C_m of the dye on the external surface of the membrane. The diminution of C_m on the external surface of the membrane diminishes the rate with which the dye diffuses into the egg and accelerates the rate with which the dye can diffuse out of the egg.

If it is legitimate to apply this reasoning to the explanation of the second group of cases of antagonistic salt action, the observed facts on the antagonism between KCl and other salts or acids could be expressed as follows: In distilled water the attractive forces acting between the outer surface of the membrane of the egg and KCl are very strong and hence the concentration C_m of this salt at the outer surface of the membrane reaches a high value; while these forces of attraction between KCl and the outer membrane are diminished when salts or acids are added to the outer medium in the proper concentration. This explains why the recovery of the embryo poisoned in KCl is very slow when the egg is put into distilled water, since in this case the concentration of the KCl (or other K salts) at the outer surface of the membrane remains very high and thus prevents the diffusion of KCl from the interior of the egg into the distilled water; while if a salt in a sufficiently high concentration is added to the distilled water the value C_m of KCl on the outside surface of the membrane is diminished and the barrier to

the diffusion of the KCl from the interior of the egg to the outside solution is removed.

This theory holds probably for all cases of the second group of phenomena of antagonism, namely where salts (and possibly acids) in general antagonize the injurious action of an electrolyte. It must remain for further investigations to decide whether it holds also for the first group of cases of antagonism where the injurious action of high concentrations of a salt with a monovalent cation (e.g., NaCl) is inhibited by traces of a salt with a bivalent cation (e.g., $CaCl_2$). The two groups of phenomena are in one respect the converse of each other, since in the first group the efficiency of the antagonistic action increases with the valency of the cation, while in the second group the antagonistic action increases with the valency of the anion of the antagonistic salt.

[1] Loeb, *Archiv ges. Physiol., Bonn*, **88**, 68 (1901); *Amer. J. Physiol.*, **6**, 411 (1902).
[2] Loeb, *Archiv ges. Physiol. Bonn*, **107**, 252 (1905).
[3] Loeb, *Biochem. Zs.*, **47**, 127 (1912).
[4] Osterhout, *Science*, **35**, 112 (1912); *Bot. Gaz., Chicago*, **59**, 317 (1915).
[5] Loeb and Wasteneys, *Biochem. Zs.*, **31**, 450 (1911).
[6] Loeb, *Ibid.*, **43**, 181 (1912).
[7] Loeb and Wasteneys, *Ibid.*, **33**, 489 (1911); **39**, 167 (1912).

THE NITROGEN PROBLEM IN ARID SOILS

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Standing eminent, if not preëminent, everywhere, in considerations of soil fertility, the nitrogen problem is especially so under arid soil conditions. The acuteness of the situation in the latter has been recognized, however, by neither the scientist nor the practical man until recently when certain investigations on the one hand, and certain field manifestations on the other, have caused to stand out in sharp relief the nitrogen question from among others in California's soil puzzles. It is with reference to some of these recent findings, and their bearing on problems of soil fertility in California, that this brief paper is written as a forerunner of more detailed discussions soon to appear elsewhere.[1]

Considering only the average nitrogen-content of California soils, as based on a thousand or more analyses, the student of the subject does not obtain a true picture of the paucity in nitrogen which characterizes our truly arid soils. For many of our soils are situated in regions of heavy winter rainfall and produce a luxuriant spring growth;

hence their nitrogen-content, owing to the large supply of decaying organic matter, may compare very favorably with that of an average soil of the humid region. In our truly arid soils, however, which receive fifteen inches of rainfall per year or less, it is quite the usual thing to find the total nitrogen supply below 0.05% in the air-dry surface soil. Frequently, indeed, under the conditions of the San Joaquin Valley the percentage of total nitrogen in the surface soil may be no more than 0.01% or 0.02%. Therefore, even if all of this nitrogen could be rendered available for assimilation by the plant, the soil could not be expected to produce profitable crops for more than a few years. Fortunately, the roots of plants can draw more or less freely on the nitrogen supply of the soil below the first foot in depth, and thus crops have been produced at times on soils manifestly deficient in nitrogen. It must be remembered, however, that, even in arid soils in which we commonly find nitrification proceeding at the remarkable depth of six feet below the surface, nitrification and hence the available nitrogen supply decreases in intensity rapidly with increasing depth. As a result of a total supply of nitrogen which is too meager, coupled with the relatively small fraction thereof which is rendered available as is pointed out below, nitrogen starvation with its various manifestations in different plants is one of the prominent problems of soil fertility in California, and particularly in case of nonleguminous perennial plants. To illustrate this, it may be mentioned that it has frequently been found impossible to carry young fruit trees through one season of growth in the San Joaquin Valley on soils which are otherwise well supplied with plant food elements, for lack of a proper nitrogen supply.

More frequent even than the total starvation of crop plants on our typically arid soils is the occurrence of plants which languish for several years because of an insufficient supply of available nitrogen. With my coworkers I have obtained experimental and observational data, to appear in detail later as above indicated, which point significantly to a probable causal relationship between the lack of usable nitrates in the root zone and many features of backwardness or disease in our crop plants. These data indicate, almost without exception in the soils studied, that the lack of available nitrogen referred to is to be accounted for in one or more of four ways: 1st, a lack of sufficient nitrogen in the soil in toto; 2d, a feeble nitrifying power of the soil; 3d, accumulation of nitrates in the dry surface crust of the soil in which they can not be used by the feeding roots; and 4th, denitrification of nitrates produced within or added to the soil.

Our investigations point to the conclusion that the second cause,

with certain qualifications soon to be indicated, is the most prominent of the four mentioned in connection with the nutritional problems of our crops. We are therefore in a position to confirm, as a result of our studies on truly arid soils, Stewart's[2] statement with respect to the intensity of nitrification in them, which was based on studies of the more distinctly semi-arid soils of Utah. While we possess ample evidence in support of Stewart's contention in the respect noted, I feel constrained to state that Stewart's criticism of Hilgard's explanation on the humus and humus-nitrogen question as between humid and arid soils is unwarranted by the facts, as we hope to show in detail in our forthcoming publications. The qualification which needs to be made with reference to our assertion as to the feeble nitrifying power of arid soils is that this power is more distinctly relatively rather than absolutely feeble. Thus we have found that some forms of nitrogen are very readily nitrified by certain arid soils which are not capable of nitrifying other forms of nitrogen at all. For example, the nitrogen of steamed bone-meal or cotton-seed meal or even of sulphate of ammonium is efficiently transformed into nitrate by many of our soils, which will not only produce no nitrate in a month's incubation period out of dried blood or high-grade tankage, but will even cause a loss of nitrate from that already contained in the soil. It appears further that the forms of nitrogen which nitrify most readily in humid soils give the most unsatisfactory results in arid soils as a general rule.

The nutritional factor contributing to the unsatisfactory growth of our crop plants is evidently then, in general, the soil's lack of power to transform enough of its own nitrogen supply or of the supply added in fertilizers or manures into a usable form. We must now give consideration to the theoretical aspects of the reasons underlying the condition just mentioned. There can be but little question that the feeble powers of the nitrifying flora of arid soils is primarily to be attributed to a deficiency in the supply of readily decayed organic matter in such soils. Inasmuch as the organic matter serves as a source of energy for the microörganisms, its initial small supply in virgin soils of this region coupled with the readiness with which it is depleted by oxidation, must operate to enfeeble and perhaps destroy the nitrifying bacteria. When we remember how small a supply of organic matter we start with in our soils and further that long hot dry seasons are the best of conditions for its dissipation through oxidation, it is small wonder that soil management by methods intended for application under eastern conditions should so far intensify the process, by constant tillage, that the necessary energy supply for the nitrifying bacteria should soon be so low as

to render impossible the proper activation of those organisms. To all such direct damage to the soil must be added the indirect damage to the water and air supply necessary for the bacteria which follows the loss of organic matter from soils.

Still other considerations of a theoretical nature enter into the problem. These are concerned with the causes for the unsatisfactory nitrification of the nitrogen in dried-blood, for example. We have noted in all of our experiments that ammonification of dried-blood nitrogen may proceed with vigor in the soils in question while no nitrate is produced. It appears now that in soils which produce ammonia most energetically from dried-blood nitrogen that the nitrifying bacteria are deleteriously affected by the ammonium carbonate and gaseous ammonia which the soils in question liberate in large quantity. Whether this speculation be correct or incorrect will appear from experiments which are now in progress. It appears certain however, regardless of the outcome of these experiments, that the fermentation of dried blood proceeds very differently in the 'normal' and the 'abnormal' soils which represent respectively those which nitrify the nitrogen of dried blood and those which do not. In the former soils no odor of ammonia is ever noted in the soil cultures and no other odors but those of active soil are encountered. In the latter soils not only is ammonia given off in large quantities, but it is accompanied by ill-smelling gases resulting from putrefaction.

The brief space of this paper precludes the possibility of a more detailed discussion of the large amount of experimental data which we have accumulated in our experiments with both humid and arid soils; but it may suffice here to point out some of their practical bearings.

1. The addition and maintenance of a good supply of organic matter by green manuring or by the use of barnyard manure must be practiced on all soils deficient in nitrogen and organic matter.

2. Nitrogenous fertilizers when employed on such soils must be either of the low-grade organic variety such as steamed bone meal, cotton-seed meal, and sewage sludge, or else sulphate of ammonium must be used.

3. The overheating of the soil, excessive evaporation of moisture, and oxidation of organic matter should be prevented through the use of some kind of straw or manure mulch. This is to be regarded as one of the most important measures for present and future soil management in California orchards and vineyards, when nitrogen and organic matter are deficient.

[1] *Univ. Cal. Pub., Bull. Cal. Agric. Exp. Sta.*

[2] The Intensity of Nitrification in Arid Soils, *Proc. Amer. Soc. Agron.* 4, 132 (1912).

A NOTATION FOR USE IN THE DISCUSSION OF STAR COLORS

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Presented to the Academy, August 4, 1915

The extension of absolute scales of photographic and photovisual magnitudes to the fainter stars provides a method of determining the colors of objects at present beyond the reach of spectroscopic investigation. For the statistical discussion of such color results it is convenient to adopt, tentatively at least, in place of the conventional color index, a notation similar to that used for spectral classification. Where for the latter we employ the letters *B*, *A*, *F*, *G*, etc., to represent various spectral types, we choose *b*, *a*, *f*, *g*, etc., to indicate different classes of color. When a more exact specification is required, a decimal subdivision of the classes may be employed.

Spectral type is determined by the number, character, and distribution of the lines in the spectrum. Color class depends upon the relative intensity of the continuous spectrum background in two different regions whose location varies somewhat with the instrumental equipment and the method of observing. Since both spectral type and color class stand in an intimate relation to the temperature, they are necessarily connected with each other, and when properly defined the color class indicates at once the general character of the spectrum. To secure this advantage, the classes *b*, *a*, *f*, etc., are assumed to represent the colors corresponding to the mean for typical spectra of the classes *B*, *A*, *F*, etc., respectively.

We cannot assume that there is an invariable correspondence between *b* and *B*, *a* and *A*, *f* and *F*, etc., for the observed color *C*, which specifically is represented by some one of the letters *b*, *a*, *f*, etc., may consist of at least three elements, namely,

$$C = C_S + C_{M,S} + C_\pi \qquad (1)$$

The terms in the right member are functions of the quantities represented by the subscript letters. Thus C_S depends on the spectrum S; it is the average color index corresponding to S, a mean result derived from a large number of stars. Three or four determinations are available, for example, those of King, Parkhurst, and Schwarzschild. For the Mount Wilson photometric system we may adopt provisionally

$$C_S = 0.40\,S, \qquad (2)$$

in which S has the values -1, 0, $+1$, etc., according as the spectrum is *B*0, *A*0, *F*0, etc. C_S is thus a part of the observed color index C and is expressed in magnitudes.

$C_{M,S}$ depends upon the absolute magnitude M; provisionally, at least, it must also be regarded as a function of the spectrum. Differences in absolute brightness for the same spectral type doubtless are accompanied by differences in stellar dimensions, and hence also by variations in the extent of the stellar atmosphere. These may produce modifications of intensity in the continuous spectrum, which possibly are also dependent upon the spectral type.

The last term C_π, provides for a scattering of light in its passage through space. It is a function of the parallax π or the distance Δ, but is independent of the spectrum. It may be expressed in the form adopted by Kapteyn, namely,

$$C_\pi = d\Delta \tag{3}$$

in which $\Delta = 0''.1/\pi$, while d is the change in the color index produced by an increase of one unit in the distance.

Finally, for the more precise definition of the color symbols it is convenient to suppose that the observed color index C is connected with the color classes b, a, f, etc., by the relation

$$C = 0.40s \tag{4}$$

or

$$s = 2.5C, \tag{5}$$

in which s is specifically denoted by $b0$, $a0$, $f0$, etc., when its numerical values are -1, 0, $+1$, etc., respectively. The relation is analogous to that connecting the average color index with spectral type.

Equation (1) can therefore be written in the form

$$s = 2.5\,C = S + 2.5\,C_{M,S} + 2.5\,d\Delta, \tag{6}$$

from which it appears that s differs from the spectrum S only in so far as the object in question deviates in luminosity and distance from the mean conditions underlying the color index and spectrum relation defined by equation (2). The color symbols b, a, f, etc. are thus intimately related to the spectrum symbols B, A, F, etc., and it will often be convenient to refer to them as *hypothetical spectra*.

As a matter of further notation, we may define the difference $C - C_S = C_E$ as the *color excess*, that is, the excess of the observed color over the mean color index corresponding to the spectrum S.
We have

$$C_E = 0.4\,(s - S) = C_{M,S} + d\Delta. \tag{7}$$

The color excess therefore represents the combined effect of the luminosity and distance terms, and is useful in investigations undertaken for the determination of the reality and magnitude of the phenomena giving rise to these terms.

DISTRIBUTION OF COLORS AMONG THE STARS OF N. G. C. 1647 AND M 67

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Recent investigations have given the colors of a considerable number of stars in two of the moderately large and open clusters, and it is of interest to examine the results for peculiarities of distribution and frequency. Although the data are slender, several points are revealed with some clearness.

N. G. C. 1647

The data for N. G. C. 1647 consist of effective wave-lengths for 184 stars determined by Hertzsprung.[1] Directly observed color indices[2] are also available for about 50 of these objects, but, as the two series of results are in close agreement, the discussion is based upon the effective wave-lengths alone. The following correspondences between color class[3] and effective wave length were established:

Effective Wave-Length	4190	4260	4330	4400	4470	4540A
Color Class	*b*0	*a*0	*f*0	*g*0	*k*0	*m*0

Counts within six 5′-zones gave the results in Table I, which shows the number of stars of each color within each zone, and also the totals, the relative areas of the zones, and the densities per area of 25 π sq. min. of arc.

TABLE I

Color and Distance—Number of Stars in N. G. C. 1647

COLOR	ZONE						TOTALS
	0′–5′	5′–10′	10′–15′	15′–20′	20′–25′	25′–30′	
b	2	4	5	1	1	1	14
a	8	15	16	4	9	12	64
f	12	10	14	14	7	13	70
g	0	3	4	3	4	3	17
k	0	0	4	1	7	0	12
m	1	1	1	1	1	2	7
Totals	23	33	44	24	29	31	184
Relative area	1	3	5	7	9	11	36
Density	23.00	10.99	8.80	3.43	3.22	2.81	—

A comparison of the totals for the three inner zones (N_1) with those for the three outer (N_2) suggests that the condensation may vary with

the color (second, third, and fourth columns, Table II). But the background stars, as well as the members of the cluster, are included, and it does not follow that for the cluster itself the condensation is variable.

Let us assume for a moment that the ratio n_1/n_2 for the cluster alone does not vary with the color. Its value must then be approximately that of N_1/N_2 for the b and early a stars, for it is probable that all these belong to the cluster.[4] As a round number, we may assume $n_1/n_2 = 3$.

TABLE II

Percentage of Colors in N. G. C. 1647 and Background

COLOR	TOTAL NO. STARS		N_1/N_2	n	TOTAL NO. STARS		PERCENTAGES		
	0'–15'	15'–30'			Cl.	Bkgd.	Cl.	Bkgd.	Other Reg.
b	11	3	3.7	−0.25	15	−1	14	−1	1
a	39	25	1.6	4.50	46	18	43	24	13
f	36	34	1.1	8.25	37	33	34	43	47
g	7	10	0.7	2.88	5^5	11^5	5	15	30
km	7	12	0.6	3.62	4^5	14^5	4	19	9
Totals	100	84		19.00	108	76	100	100	100

The number of background stars, n, can then be calculated for each color by

$$\frac{N_1 - n}{N_2 - 3n} = 3,$$

for which the unit of area is 225 π sq. min. The results are in the fifth column of Table II. The numbers for the cluster and the background can now be separated; their values are in the sixth and seventh columns. The percentage distribution of colors is in the two following columns. The last column shows the corresponding mean distribution for two other regions of the sky, namely, the North Pole and that of S Cygni.[4]

The background percentages were calculated on the assumption that the condensation within the cluster is the same for all colors; their agreement with the values in the last column of Table II is close enough to give some validity to that assumption. At any rate, there is no evidence for supposing that the distribution within the cluster depends upon the color.

An examination of the distribution from the standpoint of distance and brightness suggests a relatively greater condensation of the brighter stars; but from 10.5 downward the distribution seems to be the same for all magnitudes.

The apparent magnitude corresponding to maximum frequency is, however, quite different for the different colors, as Hertzsprung has already pointed out[1] and as appears from the results in Table III. From these it is seen that the magnitude at which maximum frequency occurs increases by about two magnitudes for an increase in the color of one color class. If an extrapolation of this result is to be permitted, one would infer that the majority of the *g*, *k*, and *m* stars belonging to the cluster are so faint that they do not fall within the limits of the available data. This probably accounts for the relatively small percentage of these colors found among the cluster stars. (See eighth column, Table II.)

Inasmuch as there are no reliable data for the distribution of the background stars, with respect to color and magnitude, these objects

TABLE III

Color and Magnitude—Number of Stars in N. G. C. 1647

MAG.	COLOR						TOTAL
	b	*a*	*f*	*g*	*k*	*m*	
<9.5	5	0	0	0	2	0	7
9.5–10.5	8	11	0	1	1	0	21
10.5–11.5	0	13	3	0	0	1	17
11.5–12.5	1	25	6	1	0	1	34
12.5–13.5	0	8	26	3	0	2	39
13.5–14.5	0	8	34	12	9	2	65
> 14.5	—	—	—	—	—	1	1
Totals.....	14	65	69	17	12	7	184

are necessarily included in the conclusions stated in the two preceding paragraphs.

MESSIER 67

The data consist of 231 color indices derived by Shapley with the 60-inch reflector. The distribution for color and distance is shown in Table IV. The densities in the last line indicate that here the counts have been extended beyond the boundary of the cluster, and that from 7′.5 outward the tabulated stars belong to the background.

We have, therefore, in this instance, an approximation for the constitution of the background in the direction of the cluster. After deducting the background stars and combining the results for the cluster into two zones, we find the numbers in the second and third columns of Table V. The totals for the cluster and the background, and the percentage distribution are in the remainder of the table. The percent-

ages for the background are in reasonably good agreement with those for the North Pole and the region of S Cygni given in the last column. There is no evidence of a variation of the condensation with color either before or after the deduction of the background stars.

The distribution with respect to magnitude and distance, and magnitude and color, is similar to that for N. G. C. 1647, although the color and magnitude relation is less clearly marked than was the case with that cluster.

TABLE IV

Color and Distance—Number of Stars in M 67

COLOR	ZONE						TOTALS
	0–1′.5	1′.5–3′.5	3′.5–5′.5	5′.5–7′.5	7′.5–9′.5	9′.5–11′.5	
a.....	0	2	2	0	1	1	6
f.....	5	10	9	15	11	24	74
g...	8	39	34	22	12	14	129
k....	2	7	9	2	1	1	22
Totals...	15	58	54	39	25	40	231
Relative area...	2.25	10	18	26	34	42	132.25
Density..	6.67	5.80	3.00	1.50	0.73	0.95	

TABLE V

Percentage of Colors in M 67 and Background

COLOR	CLUSTER ALONE		TOTALS		PERCENTAGES		
	0′–3′.5	3′.5–7′.5	Cl.	Bkgd.	Cl.	Bkgd.	Other Regions
a	2	1	3	3	3	3	13
f.	9	4	13	61	11	54	47
g	43	42	85	44	71	40	30
k.....	9	9	18	4	15	4	9
Totals.....	63	56	119	112	100	101	99

SUMMARY OF RESULTS

1. Neither N. G. C. 1647 nor M 67 show any dependence of condensation upon color which cannot be explained on the basis of included background stars.

2. With the possible exception of an excess of a few bright stars in the center of N. G. C. 1647, there seems to be no dependence of condensation upon magnitude.

3. There is a marked relation between color and magnitude in N. G. C. 1647; the connection is also evident, though less pronounced, in the case of M 67.

4. The probable distribution of colors in the background of N. G. C. 1647, and that actually observed for M 67, is similar to that for the North Pole and the region of S Cygni.

5. In neither case is the limiting magnitude low enough to include all the cluster stars; but as far as these limits, the percentage distribution of the different colors in the cluster is notably different from that in the background; moreover, there is a marked difference for the two clusters. N. G. C. 1647 contains a considerable number of *b* and *a* stars, and practically none of the *g*, *k*, and *m* classes, except as they may be fainter than the limiting magnitude. M 67, on the other hand, shows no *b* and only 3% of *a* stars. The maximum frequency of 71% is for *g* and, curiously enough, no *m* stars appear.

[1] *Mt. Wilson Contr.*, No. 100; *Astrophys. J.*, **42**, (1915).
[2] *Mt. Wilson Contr.*, No. 102; *Astrophys. J.*, **42**, (1915).
[3] A Notation for Use in the Discussion of Star Colors, these PROCEEDINGS, **1**, 481 (1915).
[4] *Mt. Wilson Contr.*, No. 81; *Astrophys. J.*, **39**, 361 (1914).

ON THIELE'S 'PHASE' IN BAND SPECTRA

By Horace Scudder Uhler

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In the emission spectra of all compounds and of many elements the lines start abruptly at a certain wave-length, near which they are very close together, and separate more and more as the distance from the beginning or 'head' is increased. Such spectra are called band or channeled spectra because, with relatively small dispersion, they have the general appearance of the chiaro-oscuro of a channeled column illuminated laterally. One of the problems of spectroscopy consists in finding the law governing the relative frequencies of the lines of one band or of a group of bands. In other words, the problem is to arrange the lines in series and to express their frequencies by a mathematical formula, as has been done for a fairly large number of line spectra. The analysis of a line spectrum into series is greatly facilitated and made secure by the fact that lines of the same series show their functional relationship by the similarity of the changes which they undergo when the source is subjected to pressure, or is placed in a magnetic field, etc. On the other hand, the frequencies of the lines of the majority of well-developed band spectra do not exhibit the pressure and Zeeman effects. Consequently, since physical criteria are lacking, the grouping into series of the lines of band spectra depends wholly upon the

apparent regular sequence of the lines and the degree of accuracy with which their wave-lengths or their frequencies fit a smooth curve or satisfy an empirical equation. It is therefore evident that any formula proposed for band spectra must be subjected to very severe tests before it can be accepted as an expression of a law of nature.

A very general law for all series spectra was proposed by Thiele in the year 1897. It was expressed by the equation

$$\lambda = f[(n+c)^2], \tag{1}$$

where λ denotes the wave-lengths of a line whose ordinal number is n, and c is a constant for any one series. Thiele styled c the "phase" of the series. The integer n is supposed to assume negative as well as positive values. Consequently a series must in general be composed of two groups of lines each of which would ordinarily be called a series. More precisely, the positive branch of each series must be accompanied by a negative branch of the same series, having the same head ($n = 0$) and the same 'tail' ($n = \infty$) and being represented alternately by a line in each interval of the other branch. In the case of band spectra Thiele highly recommended the special form of function (1) which he employed with apparent success in his computations of the wave-lengths of the lines of the carbon band at λ 5165 and which he wrote as

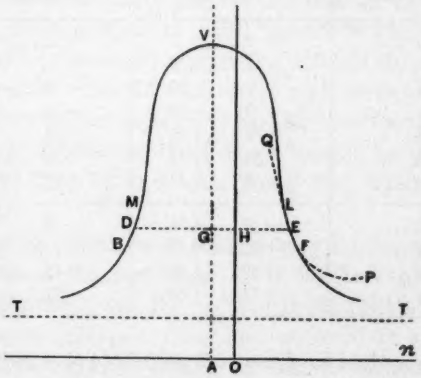
$$\lambda = \lambda_0 - \kappa\left(\frac{n+c}{10}\right)^2 \cdot \frac{1 + s_1\left(\frac{n+c}{10}\right)^2 + \cdots + s_{r-1}\left(\frac{n+c}{10}\right)^{2r-2}}{1 + t_1\left(\frac{n+c}{10}\right)^2 + \cdots + t_r\left(\frac{n+c}{10}\right)^{2r}} \tag{2}$$

The objects of the present paper are to outline a practical method for calculating *c without assuming a special form* of function (1) and to give briefly the results obtained by applying the new method to the λ 5165 carbon band and the third cyanogen band at λ 3883.

It should be remarked in advance that it is not feasible to solve equation (2) for c when a sufficiently large number of wave-lengths are used to ensure a satisfactory degree of accuracy. The adjacent figure shows the form of curve representing equation (1) in rectangular coördinates. The even power of $n + c$ involved in (1) causes the graph to be symmetrical with respect to the line AV whose equation is $n = -c$. $AV = \lambda_0$. The branches of the curve are asymptotic to the line TT' whose constant ordinate, $\lambda_0 - \kappa\, s_{r-1}/t_r = \lambda_\infty$, equals the wave-length of the tail of the series. The points of inflection express the hypothesis that the intervals between consecutive lines of the same series attain a maximum, as n increases arithmetically, and then decrease indefi-

nitely. The curve also brings out two more properties of function (1) which are that the number of lines is finite and infinite respectively in the regions of the head and tail of a band.

A straight line parallel to the axis of n, and at a suitable distance therefrom, will intersect the curve in two points, such as D and E. Hence, if n and n' denote (the algebraic values of) the abscissae of any two points on the curve which have the same value of λ, it follows at once that $c = -\frac{1}{2}(n + n')$. $[GH = c, HE = n, DH = -n'.]$ In the case of any series whose wave-lengths have been accurately determined there is no inherent difficulty associated with the calculation of n and n' corresponding to a chosen numerical wave-length. It is only necessary to evaluate the coefficients of any simple, convenient interpolation formula which represents a curve PQ fitting the locus of actual wave-lengths sufficiently closely over a limited range of spectral lines, such as FL or BM. In other words, the value of c may be obtained by taking an adequate number of terms of the power polynomial $\lambda = a_0 + a_1 n + a_2 n^2 + \ldots + a_k n^k$, determining the coefficients $a_0, a_1, \ldots, a_k$ from the known wave-lengths, substituting for λ an arbitrary wave-length (OH), and solving for n. Then using the same value of λ and repeating the process for the negative quadrant, the corresponding value of n' is computed. Knowing n and n', c follows immediately from the relation $c = -\frac{1}{2}(n + n')$. In practice I have found that three coefficients (a_0, a_1, a_2) are sufficient for all cases, that the method of least squares can be used to great advantage, and that certain transformations of coördinates simplify the computations enormously.



The accompanying table gives the values of c computed by the above method for two of the series of the λ 5165 carbon band. This band is the one investigated arithmetically by Thiele who obtained mean values of c by applying the laborious method of trial and error to formula (2). The tabulated values of the phase were calculated from the more recent and accurate wave-lengths published by Leinen in the year 1905.

The numbers in the fourth column show conclusively that c is not

strictly constant for either the α or the δ series of the λ 5165 carbon band. In the case of the α series the phase increases from about 0.263 to 0.268 at least, while for the δ series it decreases from 0.250 to 0.235 or less. The values of c used by Thiele were 0.266 and 0.2445 for the α and δ series respectively.

The fact that the variations of the phase are real and not fictitious may be established by the following considerations. Each of the seven lines +36 to +42 would have to be displaced in the same direction, relatively to the corresponding group of lines (−37 to −43), by 0.104 A to change the value of c from 0.2686 to 0.2629. This shift is too great to be admitted, for, the *arithmetical sum* of all the fourteen residuals ($\lambda_{calc.} - \lambda_{obs.}$) divided by 14 only equals 0.007 A. In like manner, for the δ series, the average residual is 0.016 A whereas the displacement

SERIES	+ BRANCH . n .	− BRANCH . n'.	c	λ INTERVAL
α.....	+ 3,...,+ 9	− 3,...,− 9	0.2632	5164.4−5153.4
α.....	+ 3,...,+ 9	− 4,...,−10	0.2633	
α.....	+ 9,...,+16	− 9,...,−16	0.2626	5155.7−5129.8
α.....	+ 9,...,+16	−10,...,−17	0.2625	
α.....	+20,...,+26	−20,...,−27	0.2666	5116.0−5075.5
α.....	+36,...,+42	−36,...,−42	0.2684	5008.0−4944.9
α.....	+36,...,+42	−37,...,−43	0.2686	
δ.....	+ 8,...,+18	− 8,...,−18	0.2499	5156.3−5119.4
δ.....	+23,...,+29	−23,...,−29	0.2417	5095.4−5052.8
δ.....	+35,...,+41	−35,...,−41	0.2375	5009.6−4951.6
δ.....	+52,...,+60	−52,...,−60	0.2344	4843.2−4746.6

required to change c from 0.2344 to 0.2499 would be 0.355 A. By applying the same method and tests to the two apparent series of doublets which start at the first head of the λ3883 cyanogen band I have been able to show that these series cannot be combined as the positive and negative branches of a single Theile series with a constant phase.

In conclusion, it may not be superfluous to remark that equation (2) is unsatisfactory in two respects: (*a*) as an interpolation formula it is too complicated, since modern wave-lengths require the retention of at least eight parameters, and (*b*) it predicts tails much too far away from the heads and in a region of the ultra-violet where no tails have been found experimentally. For additional details and comments reference must be made to the *Astrophysical Journal* in which the present paper will be presented in full.

WHY POLAR BODIES DO NOT DEVELOP

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Since the work of O. Hertwig (1890) and Boveri (1891) it has been known that the two small cells which are formed at one pole of the egg during its maturation divisions and which have long been known as 'polar bodies' since they mark out the 'animal' or ectodermal pole of the egg are homologous with cells which in the male give rise to functional spermatozoa, so that the polar bodies are generally recognized as small and non-functional egg cells, a view which was first set forth by Mark (1881). Before the two maturation divisions which lead to the formation of eggs or spermatozoa the sex cells are called 'oöcytes' in the case of the female, 'spermatocytes' in the case of the male; after the first maturation division they are called 'second oöcytes' or 'second spermatocytes' and after the second maturation division they are known as 'oötids' or 'spermatids.' In the case of the male both of these divisions are equal and all of the spermatids may become functional spermatozoa, in the female both maturation divisions are usually very unequal the smaller division product in each case being the 'polar body,' and the larger the 'egg.'

In many animals the maturation divisions of the egg may be made approximately equal by pressure or by centrifugal force so that the difference in size between the polar body and the egg largely disappears. Thus if the eggs of the gastropod *Crepidula plana* are subjected to a centrifugal force of about 600 times gravity during the first or second maturation divisions some of the eggs in which the axis of centrifuging coincides with the axis of the division figure, or spindle, divide into approximately equal halves. In my experiments on the eggs of Crepidula the giant polar body is usually the second one since the eggs were centrifuged in most cases during the second maturation division; when the centrifuging occurred during the first maturation the first polar body is the giant one; when it occurred during both maturation divisions both polar bodies are abnormally large. Nevertheless only one of these cells develops.

In this animal the spermatozoon always enters the egg during the first maturation division and usually at the pole opposite that at which the polar bodies normally lie. In normal cases therefore the spermatozoon is always found in the 'egg' or larger daughter cell and never

in the polar body; and even when the two daughter cells are made equal by pressure or by centrifugal force the spermatozoon always lies in one daughter cell and not in the other. The same is true if the centrifugal force is applied during the second maturation division; although the daughter cells may be equal in size the spermatozoon is found in only one of these cells. Subsequent events show that only that cell develops which contains the spermatozoon.

In Crepidula and many other mollusks as well as in annelids and ascidians the spermatozoon normally enters the egg at the beginning of the first maturation division and always before the first polar body is cut off. Indeed the first maturation spindle will usually remain in the metaphase, or middle stage of division, until a spermatozoon enters or until the egg is stimulated by other means (artificial parthenogenesis) to begin development. As soon, however, as a spermatozoon enters an egg the maturation division proceeds and the whole process of development is set in motion in the cell which contains the spermatozoon. But the polar bodies, which do not contain the spermatozoon, never develop even though they may be as large as, or even larger than, the egg which does develop.

The giant polar bodies of Crepidula resemble unfertilized eggs in that the cytoplasm remains diffused throughout the whole cell whereas in eggs after fertilization there is a fairly sharp separation of cytoplasm and yolk. Associated with this lack of segregation of cell substances there is also a lack of distinct polar differentiation in giant polar bodies. The intra-cellular movements which lead in the fertilized egg to the segregation of cytoplasm at the animal pole and of yolk at the vegetative pole do not take place in giant polar bodies.

These giant polar bodies invariably contain a nucleus and they may contain samples of all the substances found in the egg; they may contain most of the protoplasm of the egg; they may be larger than the cell which does develop but the one thing which they lack is a spermatozoon, whereas the egg cell which does develop invariably contains a spermatozoon. We must conclude therefore that the giant polar bodies of Crepidula do not develop because they do not contain a spermatozoon.

The failure of normal polar bodies to be fertilized and to develop is generally held to be due to their small size, but even when these polar bodies are large as is sometimes the case in mollusks, polyclads and nematodes they do not undergo fertilization and do not delevop though they sometimes divide once or twice. In one case only has the development of a polar body, or rather of both second oöcytes, been observed.

Francotte (1898) discovered in the polyclad Prostheceraeus that at the first maturation the egg sometimes divided into two nearly equal cells; each was then entered by a spermatozoon and normally fertilized and at the second maturation division each formed a small second polar body and the larger cells then underwent normal cleavage and developed to the gastrula stage. In a few other instances the entrance of a spermatozoon into a polar body has been reported though some of the cases are not entirely convincing and need verification. Thus Platner (1886) described the entrance of a spermatozoon into a polar body of Arion; he maintained that the polar bodies are formed before the entrance of the sperm, which would make this case similar to that of Prostheceraeus, but the evidence is by no means conclusive. Sobotta (1895) calls special attention to the large size of the polar bodies in the mouse and suggests that they may be capable of being fertilized but offers no evidence in favor of this view. Kostanecki (1897) has observed a spermatozoon with its head penetrating the second polar body of Physa, a thing which he regards as merely a 'curiosity.'

Lefevre (1907) observed that the polar bodies of Thalassema undergo several cleavages resulting in the formation of a morula-like cluster of minute cells when they are exposed to weak solutions of HCl;" thus they respond to the same divisional stimulus supplied by the acid solutions as does the egg cell itself."

The most striking difference between Prostheceraeus and other animals in which giant polar bodies have been reported is to be found in the fact that in the former fertilization does not take place until after the first maturation division is completed and then each of the daughter cells is fertilized, whereas in the latter the entrance of the spermatozoon occurs before the completion of the first maturation division with the result that one of the daughter cells contains a spermatozoon and the other does not.

In this fact is to be found the explanation of the different behavior of the giant polar bodies of Prostheceraeus and of Crepidula, for it is well known that one of the first effects of the entrance of a spermatozoon into an egg is the prevention of other spermatozoa from entering. If the spermatozoon enters the egg before the first polar body is cut off that polar body as well as other cells which are formed later from the egg are rendered "immune" to other spermatozoa.

But although the influence of the entering spermatozoon spreads so rapidly over the egg that within a few minutes at most it renders all portions of the egg surface 'immune' to other spermatozoa and thus prevents the fertilization of polar bodies which are formed after fertili-

zation, this influence does not go so far as to cause the polar bodies to develop, even though such polar bodies may be formed several hours after the spermatozoon enters the egg. In Crepidula the second polar body is formed about three hours after the entrance of the spermatozoon into the egg, and during this time the sperm head has grown into a vesicular nucleus and the sperm aster has become quite large, but in spite of this the spermatozoon has not sufficiently affected the egg substance to cause the second polar body to develop even though that body may contain the larger part of the egg protoplasm. Only that portion of the egg develops, in such cases, in which the sperm nucleus and aster are present.

This conclusion is similar in many respects to that reached by Zeigler (1898) who found that when eggs of the sea urchin, *Echinus microtuberculatus*, were constricted by cotton fibers under pressure only that portion of the egg which contained the sperm segmented while the portion containing the egg nucleus never divided, though its nucleus frequently went through the division phases, but without any division resulting. In this case the portion of the egg containing the sperm might remain for some time connected with the other portion by a narrow neck, and yet the influence of the sperm in the one half did not cause the other half to develop.

These facts are of interest because of their bearing on the nature of one of the processes concerned in fertilization. In a series of important and extensive works on artificial parthenogenesis and fertilization which he has summarized in a recent book Loeb (1909) has shown that at least two factors are involved in artificial parthenogenesis, (1) an external factor, such as butyric acid, which causes a cytolysis of the cortical layer of the egg followed by increased oxidation and which leads to the rapid disintegration of the egg at normal temperatures, and (2) an internal factor, such as hypertonic solutions, lack of oxygen, etc., which inhibits this disintegration. Loeb concludes that in normal fertilization also both of these factors are present and that the spermatozoon carries substances into the egg which (1) cause cytolysis of the cortical layer and increased oxidation and also other substances which (2) inhibit this cytolysis before it leads to the disintegration of the egg.

My experiments on the giant polar bodies of Crepidula show that changes in the cortical layer which prevent the entrance of a second spermatozoon take place very rapidly over the entire egg, but that the spermatozoon which enters does not cause any portion of the egg to develop except the cell in which it lies. Although the spermatozoon enters the egg of Crepidula about three hours before the formation of

the second polar body the influence of the spermatozoon on the egg protoplasm during this time is not sufficient to start development in the second polar body even though it may contain the greater part of the egg substance.

This indicates that the second factor concerned in the process of normal fertilization is not to be found in the diffusion through the egg of some chemical substance carried in by the spermatozoon but is some non-diffusable substance, probably an organic structure.

Long ago Boveri (1887) showed that under certain circumstances the egg of Ascaris may divide at the first cleavage so that half of the egg nucleus passes into each daughter cell while the sperm nucleus does not divide but goes entire into one of the first two cells. Such a condition he called 'partial fertilization,' and in such cases he found that both halves of the egg develop, thus showing that the activating influence of the spermatozoon has affected both halves. Since in this case the centrosome is the only structure derived from the spermatozoon which is known to go into both cleavage cells he reached his well known conclusion that the essential thing in fertilization is the addition of a centrosome to the egg cell.

It is possible of course that other unrecognized structures are introduced by the spermatozoon and serve to activate the egg. Meves (1911) found that the spermatozoon of Ascaris introduces into the egg a number of coarse granules, the 'plastochondria,' which he thinks unite with similar granules in the egg and are then distributed to the cleavage cells. However, in one of the Echinids he finds that the large granule or 'plastosome' which is derived from the middle-piece of the spermatozoon goes into one only of the first two cleavage cells and yet both develop. I have found that the 'plastosomes' in the eggs of gastropods and ascidians may be distributed very unequally to the first two cleavage cells without interfering with the further division of both cells, and there is no evidence whatever that the activating influence of the spermatozoon is due to these granules.

On the other hand many investigators have held that fertilization is essentially a chemical process and that the activation of the egg depends upon the introduction by the spermatozoon of certain chemical substances which diffuse through the egg.

The observations recorded in this paper indicate that the second or internal factor in normal fertilization is a non-diffusable substance which is introduced by the spermatozoon, and they strongly suggest that this factor is the sperm centrosome, a position which Boveri has long maintained and which I have hitherto contested.

In conclusion, giant polar bodies do not develop because they are not fertilized and they are not fertilized because they are generally formed after a spermatozoon has entered the egg and has rendered it impervious to other spermatozoa.

REFERENCES

Boveri, Th. (1887). Ueber den Anteil des Spermatozoon und der Teilung des Eies. *München, SitzBer. Ges. Morph.*, 3.
(1891). Befruchtung. *Merkel u. Bonnet Ergebnisse* 1.
Francotte, P. (1898). Recherches sur la maturation, la fecondation et la segmentation chez les Polyclads. *Arch. zool., Paris*, 6.
Hertwig, O. (1890). Vergleich der Ei- und Samenbildung bei Nematoden. *Arch. mikr. Anat., Bonn*, 36.
Kostanecki, K. (1897). Ueber die Bedeutung der Polstrahlung, etc., *Ibid.*, 49.
Lefevre, G. (1907). Artificial Parthenogenesis in Thalassema mellita. *J. Exp. Zool.*, 4.
Loeb, J. (1913). Artificial Parthenogenesis and Fertilization, Chicago.
Mark, E. L. (1881). Maturation, Fecundation and Segmentation of Limax Compestris. *Bull. Mus. Comp. Zool. Harvard*, 6.
Meves, Fr. (1911). Ueber die Beteiligung der Plastochondrien an der Befruchtung des Eies von Ascaris megalocephala. *Arch. mikr. Anat.*, 76.
(1912). Verfolgung des sogennanten Mittelstückes des Echinindenspermiums im befruchteten Ei, etc. *Ibid.*, 80.
Platner, G. (1886). Ueber die Befruchtung von Arion Empiricorum. *Ibid.*, 27.
Sobotta, J. (1895). Die Befruchtung und Furchung des Eies der Maus. *Ibid.*, 40.
Ziegler, H. E. (1898). Experimentelle Studien ueber die Zellteilung. *Arch. Entw. Mech., Leipzig*, 6.

RADIAL VELOCITIES OF THE PLANETARY AND IRREGULAR NEBULAE

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In a former number of the PROCEEDINGS[1] one of the authors presented results on the radial velocities of 54 gaseous nebulae determined by spectrographic methods at the Lick and D. O. Mills Observatories, working respectively in the northern and southern skies. It was there shown that the planetary nebulae, or those of regular form, are rapid travelers in comparison with the stars, a fact which casts serious doubts upon the generally accepted hypothesis that the stars have been formed from planetary nebulae by processes of evolution.

During the past year observations at both institutions have been extended to fainter members of this class of objects, and there are now available some 348 measures of the velocities of approach and recession of 92 gaseous nebulae, or those whose spectra are composed of bright lines.

Before proceeding to a discussion of the results, those for 12 nebulae situated in the Magellanic Clouds are set aside for special consideration, since, as will be shown later, they are attended by conditions which are not representative of nebulae in other portions of the sky. There remain 80 observed objects, of which 7 are extended or irregular in form, and 73 have the forms characteristic of planetary and ring nebulae. When all the observed velocities have been freed from the effects of the solar motion, the average velocities of approach and recession of the various groups are found to be:

Of 7 extended nebulae	10 km./sec.
Of 73 planetaries or regular form	39 km./sec.
Of 34 'stellar' (less than 5″ diameter)	50 km./sec.
Of 39 non-stellar (disks and rings)	29 km./sec.

The velocities of the few extended nebulae thus far observed are low and of the order of the average velocity of stars of Class B, a result which is not surprising in view of the intimate relationship known to exist between these two classes of objects. The average velocity of the 73 planetaries is, on the other hand, more than six times that of the Class B stars. That planetary nebulae will eventually become helium stars can scarcely be questioned, but the old hypothesis that helium stars have in general evolved from planetary nebulae hardly appears tenable.

A division of the 73 planetaries into two groups according to their apparent size brings out a further relation of great interest The 34 nebulae which are described in the catalogues as 'stellar,' or those whose apparent diameter is less than 5″, are found to be traveling almost twice as fast as the 39 nebulae of greater apparent diameter whose forms are those of hazy disks or of concentric or superimposed rings. If these stellar nebulae are small objects their higher velocities may be in harmony with recent indications concerning stellar motions to the effect that the stars of small mass are traveling more rapidly than those of great mass. On the other hand, if they appear smaller on account of their greater distance, an analogy is suggested to the recent results obtained by Adams, that the more distant stars of certain spectral classes are traveling more rapidly than those which are nearer to us.

Attention was called in the earlier paper to the fact that the nebular velocities are distributed with more or less equal frequency for speeds of all observed magnitudes, a circumstance in marked contrast with the helium stars, whose peculiar motions follow pretty closely the 'probability curve.' Similar conclusions even more strongly marked may be drawn for the distribution of the velocities of the 34 stellar nebulae.

For an assumed apex of the sun's way at Right Ascension 270° and Declination +30°, the 73 planetaries give a solar velocity of 2.01 km./sec., while the 7 extended nebulae give 20.7 km./sec. These values are in remarkable accordance with that derived from 225 Class B stars, namely, 20.2 km./sec.

When the results for the 73 planetary nebulae are examined for the existence of preferential motions, in accordance with Kapteyn's two star-stream hypothesis, it is found that they show a marked preference for motions making small angles with the line joining Kapteyn's two vertices. A similar indication is shown when the velocities of these nebulae are grouped with reference to their distances from the central line of the Milky Way, a conclusion which is entitled to less weight, since only 10 of these objects are situated more than 20° from the galactic plane.

The fact that the gaseous nebulae have motions which are characteristic of the stars, as shown by the value of the solar motion derived from them, and by their exhibiting the phenomena of star streaming, taken together with their strong concentration in the Milky Way, affords a reliable basis for the view, frequently expressed, that these nebulae are members of our stellar system.

Since the announcement[2] by Dr. Wilson of the high velocities of 5 nebulae in the Magellanic Clouds, 7 more of these objects have been observed. The only known nebula in the Lesser Cloud has a velocity of recession of 149 km./sec., while 11 nebulae observed in the Greater Cloud have velocities of recession ranging between +237 and +287 km./sec.

In as much as gaseous nebulae are unknown in the surrounding regions of the sky, it is a fair assumption that all of these bright-line objects are within the structure of the two Clouds. It is therefore probable that the velocity of the Greater Cloud with reference to the stellar system is approximately the average velocity of the 11 nebulae observed within it, or 262 km./sec. recession. The observed velocity for only one object in the Lesser Cloud is hardly sufficient to justify an analogous hypothesis for it. However, the similarity in the appearance of the two clouds and their proximity to each other lead to the suspicion that a more or less intimate relationship may exist between them. Furthermore, the high galactic latitudes of these objects, coupled with their high velocities with reference to the centroid of stars, lends some support to the hypothesis that the Magellanic Clouds are isolated cosmic units, systems which have no apparent connection with our own stellar system.

[1] These PROCEEDINGS, 1, 8 (1915).
[2] *Ibid.*, 1, 183 (1915).